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PICKERING NGS 'B': UNITS 5 AND 8 MODERATOR PIPING VIBRATION STUDY

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ABSTRACT

An extensive vibration monitoring program was performed on the moderator inlet piping in Unit 6 following the fatigue failure of the piping at the penetration to the calandria. As a result of the Unit 6 work, documented in report 87-85-K, further vibration monitoring was carried out in Units 8 and 5. The goals of the Unit 8 and Unit 5 vibration monitoring programs were to determine the source of the vibration and implement an effective solution to the problem. Complete documentation of the vibration monitoring programs, including results and successful conclusion are contained in this report.

job	file	date	report no.
27-504-052	825.31	September 15, 1988	88-180-K

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EXECUTIVE SUMMARY

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The discovery of the fatigue failure of the main moderator inlet piping at the penetration to the shield in Pickering NGS B, Unit 6 necessitated the execution of an extensive vibration monitoring program on the inlet piping in Unit 6, the results of which are documented in report 87-85-K. Inspection of other units revealed that the problem was generic. Further vibration monitoring was performed in Units 8 and 5 to define the cause of the problem and implement remedial action.

In Unit 8 vibration monitoring was performed on the outlet piping where flow rates were in the same Reynolds' number range as that of the inlet piping. Vibration measurements were taken on the inlet piping to determine the effect of the addition of a piping support on the two branches of the inlet line above the tee. The Unit 8 monitoring program revealed that the vibration problem was specific to the inlet piping: the outlet piping vibration levels were 50% below those measured on the inlet piping for the same flow velocities. The support above the tee on the inlet piping did not reduce the vibration levels.

The results of the Unit 8 program led to the identification of the orifice in the inlet piping as the main source of the vibration. The orifice plate was replaced in Unit 5 by a two-stage energy dissipater. In the Unit 5 vibration monitoring program, performed following the installation of the dissipater, vibration, pressure and vibroacoustic measurements were carried out. The dissipater successfully reduced vibration levels by a minimum of 40% to levels comparable to those on the outlet piping. The dissipaters were subsequently installed in the other units.

The vibration monitoring program and results for the Unit 8 and Unit 5 work are documented in the report.

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27-504-052	825.31	September 15, 1988	88-180-K

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PICKERING NGS 'B': UNITS 5 AND 8
MODERATOR PIPING VIBRATION STUDY

H.L. Anderson

1.0 INTRODUCTION

Following the failure by fatigue of the moderator inlet piping at the penetration to the shield at Pickering NGS 'B', Unit 6, an extensive vibration monitoring program was carried out on the moderator piping in, sequentially, Units 6, 8 and 5 during unit outages. (After the initial Unit 6 failure, subsequent inspection of other units revealed the failure at the penetration to be a generic problem.)

The purpose of this report is to document the results of the Unit 8 and Unit 5 vibration monitoring program. The report on the Unit 6 vibration monitoring program, OHRD report 87-85-K, represents the main reference document for the subsequent work on Units 8 and 5/1/.

The vibration monitoring program was composed of the following elements:

1. Modal analysis using impact testing (all pumps off).
2. Vibration and Pressure monitoring at various operating conditions.
3. Vibroacoustic monitoring for flow phenomena such as cavitation.
4. Ultrasonic flow measurements.

The monitoring performed on the three units comprised surveys on the segments of the inlet moderator lines leading from the heat exchangers to the shield penetrations, shown in Figures 1 and 2, and the outlet moderator lines from the shield penetrations through the moderator pumpsets to the heat exchangers, shown in Figures 3 and 4.

The vibration measurements in Unit 6 covered the inlet piping only. The survey on the Unit 6 moderator inlet lines revealed the following:

1. The piping was responding at several frequencies with a dominant large bending mode at 9 Hz on the vertical rise to the penetrations, consistent with the failure of the pipe.

2. With four pump operation (normal mode) vibration levels on the inlet line from the exchangers to the penetrations were in excess of the allowable level of 40 mm/s peak, and at many locations exceeded 100 mm/s peak; near the failure location at the penetrations the vibration levels were 70 mm/s peak or greater. Noise levels in the vicinity of the piping were very high.

3. With 3 pumps the levels were reduced significantly but still exceeded the allowable of 40 mm/s peak.

4. Flow rates measured with an ultrasonic flow meter were close to system design calculations.

5. Strong cavitation was detected by the vibroacoustic technique downstream of the orifice and just upstream of the penetrations (see Figure 1).

In the Unit 8 outage the following tests were performed:

1. Modal analysis and vibration measurements on the outlet piping where flow rates were in the same Reynolds' number range as the inlet piping.

2. Vibration monitoring on the inlet lines as in Unit 6 and with the addition of a piping support on the two branches of the inlet lines above the tee.

3. Further vibroacoustic measurements on the inlet lines.

The results of the Unit 8 and Unit 6 surveys suggested that there existed in the inlet piping a source of high turbulent flow excitation that was dissipated in the passage through the calandria: the outlet piping vibration levels, measured in Unit 8, were at or below the allowable levels for piping and 50% below those measured on the inlet piping for the same flow regime.

The main source of the vibration was postulated to be from the orifice plate in the inlet piping (Figure 1). The orifice plate was replaced in Unit 5 by a two-stage energy dissipater designed by Nuclear Systems and Mechanical Design Department personnel.

In the Unit 5 work vibration, pressure and vibroacoustic measurements were performed on the inlet piping following the installation of the dissipater. The dissipater successfully reduced vibration levels in the inlet piping by a minimum of 40% to levels comparable to those on the outlet piping.

2.0 MONITORING PROCEDURE AND INSTRUMENTATION

The vibration measurements performed in Units 8 and 5 will be summarized separately.

The instrumentation and analysis procedure used in the monitoring program were the same as those used in Unit 6 except that Dytran accelerometers and preamplifiers were used in Units 5 and 8/1/.

2.1 Unit 8 Vibration Measurements

The Unit 8 vibration measurement program had the following goals:

(a) Determine the vibration levels on the outlet piping under operating conditions.

(b) Perform modal analysis on the outlet piping to check for a possible frequency match between the pumps and the piping.

(c) Determine the effect of a support installed on the inlet piping above the tee at positions 5 and 6 (Figure 2).

The Unit 8 vibration measurement program was divided into three phases which are described below.

2.1.1 Phase I

Phase I work was performed under the following conditions:

(i) Pumps in operation; and
(ii) support above tee not connected (ie, unclamped).

1. With pumps 1, 2, 3 and 4 in operation a vibration survey was performed on the inlet piping at positions 1 to 10 (Figures 1 and 2).

2. With pumps 1, 2, 3 and 4 in operation a survey of the outlet piping was performed at every other monitoring position shown in Figures 3 and 4. (Monitored at half of the 51 positions marked on the piping).

3. Four positions 4, 11, 21 and 44, on the outlet piping were selected, on the basis of the results of step 2, for monitoring vibration response with the following pump combinations:

   (i) pumps 2, 3, 4 and 5
   (ii) pumps 2, 3, and 4
   (iii) pumps 1, 2, and 3.

2.1.2 Phase II

All moderator pumps were shutdown and modal analyses were performed on both the inlet and outlet piping.

The modal analyses were performed using a hammer instrumented with a force transducer. Force input and piping response were recorded on tape and analyzed later in the laboratory.

1. On the outlet piping the modal analysis was performed as follows:

   (i) Pump 3 was the impact location for determining the response at locations 1 through 12, 26 to 28 and 34 through 51.

   (ii) Pump 4 was the impact location for determining the response at locations 13 through 25 and 29 through 33.

   Three series of impacts were performed, one set in each of the three directions, vertical, North-South and East-West. Good coherence, > 95%, between input force and response was achieved in the tests. Modal analysis, using the mobility transfer function was performed using the Nicolet 660B analyzer.

2. The modal test on the inlet piping was performed by impacting the piping at location 9, in repetition of the Unit 6 work/1/. Responses were recorded at positions 1,2,7 and 9. Two series of impacts were carried out, one set in the E-W direction and one set in the N-S direction. Vertical impacts could not be executed at location 9. As in the outlet piping tests, good coherence was obtained in the testing. Modal analysis was performed using the mobility transfer function.

   The inlet modal analysis was performed with the support above the tee unclamped. The inlet modal analysis was then repeated with the support above the tee clamped in position.

2.1.3 Phase III

With the support above the tee clamped on the inlet piping, the inlet piping response at locations 1 through 10 was surveyed with pumps 1, 2, 3 and 4 in operation. The survey was repeated with pumps 2, 3, and 4 in operation.

2.2 Unit 5 Vibration Measurements

The Unit 5 vibration measurements were taken on the inlet piping following the installation of an energy dissipater in place of the orifice plate shown in Figure 1. The measurement locations for the Unit 5 program were the same as those used in the Unit 6 and 8 inlet pipe work, as shown in Figure 1.

The energy dissipater was a flanged piping section composed of two 31.8 mm thick perforated plates separated by 0.97 m (38 inches) of pipe. The two perforated plates consisted of 85 holes of 24.6 mm diameter. The holes were on a 31.1 mm triangular pitch. The upstream edge of each hole was rounded to smooth the entry. The details on the design performance calculations of the energy dissipater are contained in reference 2.

The vibration monitoring procedure is outlined below:

1. With four moderator pumps in operation, pumps 1, 2, 4 and 5, a vibration survey was performed at locations 1 through 10, 12, 17 and 18.

2. Accelerometer blocks were fixed at locations 3, 4, 5 and 6 and measurements taken with three pumps in operation, pumps 1, 2 and 5.

Pressure measurements were also taken during the Unit 5 tests from pressure transducers placed in the piping during the outage for installation of the energy dissipater.

3.0 RESULTS AND DISCUSSION

3.1 Unit 8 Measurements

3.1.1 Modal Analysis

3.1.1.1 Inlet Piping

The modal analysis of the inlet piping was performed in detail in the Unit 6 monitoring program/1/. The modal analysis for Unit 8 on the inlet piping was performed on only four points on the piping to determine the effects on piping response of the support installed above the tee.

The response frequencies determined for the "free" and clamped conditions on the inlet pipe are documented in Table 1.

Detailed mode shapes could not be determined with only four measurement points. However, comparison of the data from "free" response of the Unit 8 pipe with that from Unit 6 shows good correlation between the piping response at the corresponding measurement points of both units.

The support had the effect of stiffening the pipework to eliminate the response at the lowest frequencies measured in the "free" condition, 9.5 to 10.5 Hz.

The modal results will be discussed further in section 3.1.2 on the vibration measurement with the pumps in operation.

3.1.1.2 Outlet Piping

The modal analysis was performed on the outlet piping to characterize the system in order to determine if the system structural natural frequencies were close to the pump operating speed.

The structural (bending mode) frequencies detected by modal analysis in the vicinity of the pumps are documented in Table 2. The frequencies detected in the piping correlate well with those detected on the pumpsets during commissioning tests/3/.

The pumpsets operate at approximately 30 Hz for which there does exist a piping structural natural frequency as determined by the modal analysis. The results of the modal analysis on the outlet piping will be discussed in section 3.1.2 with respect to the operating vibration measurements.

3.1.2 Vibration Measurements with Pumps in Operation

The results of the vibration measurements taken from PNGS Unit 8 moderator piping with the pumps in operation are summarized in this section.

The vibration data have been analyzed based on the criterion that vibration of 40 mm/s peak is excessive with levels over 100 mm/s peak requiring immediate attention/4/. The criterion was applied and proved realistic with the Unit 6 failure and will be applied to the Unit 8 and 5 data for consistency/1/.

3.1.2.1 Inlet Piping

The peak vibration velocity levels measured on the inlet pipe with four pumps in operation for both the free and clamped conditions are documented in Tables 3 and 4. The data listed in Table 3 were band-pass filtered 4 Hz to 120 Hz to reduce the effect of flow noise on the bending mode vibration data. The Table 4 data is wideband data and has been included to demonstrate the effect of the higher frequency (up to 15 kHz) components on the overall vibration levels.

The vibration levels measured on the inlet pipe, both free and clamped, were of the same order of magnitude as those measured in Unit 6. The vibration levels exceeded the allowable criteria; in several locations the vibration exceeded 100 mm/s.

The effect of the clamp was detrimental to the vibration levels, particularly in the east-west direction near the penetration, as shown by the data from locations 1 to 4. The east-west direction was the critical direction for failure in Unit 6/5,6/.

The effect of the clamp on the frequency response of the piping observed in the modal tests was confirmed in the data with the pumps in operation. The comparison of free and clamped vibration spectra at locations 5 and 6, near the clamp, as shown in Figure 5 demonstrated that the clamp eliminated the low frequency response at 9 Hz and shifted the pipe response to 26 to 29 Hz.

As observed in the Unit 6 work, persistent cavitation was detected downstream of the orifice.

The reduction in flow with three pumps in operation had the effect of reducing the response by approximately 50% at most locations; however, the vibration still exceeded the 40 mm/s peak level at some critical locations.

3.1.2.1 Outlet Piping

The peak vibration velocity levels detected on the outlet piping with four pumps in operation are listed in Table 5. The data in Table 5 represent the wide band response up to 15 kHz to include the flow noise effect.

The vibration levels on the outlet piping for four pump vibration were significantly lower, by approximately 70%, than those on the inlet piping for flow in the same Reynolds number range. The vibration levels were at or below the 40 mm/s peak allowable level.

The response spectra from the outlet piping with the four pumps in operation are consistent with the modal frequencies detected in the absence of flow. Response spectra are contained in Figures 6 to 12.

The dominant response modes with the pumps in operation were at 11.25 Hz, 30 Hz and multiples of 30 Hz.

Figures 6 through 10 are spectra from the piping just downstream of the pumps. A dominant response at 30 Hz would be expected with flow since the pumps operate at approximately 30 Hz. Far upstream of the pumps the spectra from the outlet piping near the shield wall, locations 1 and 13 shown in Figures 11 and 12, indicate a strong response at 30 Hz and its multiples again. Given that the piping responds at 30 Hz in the absence of the forcing input of the pumps and that the piping structural mode at 11.5 Hz was also measured on the pumpsets during commissioning, strong coupling of response may be occurring between the piping and pumpsets/3/. While the piping vibration measurements indicate that the response of the piping is not excessive, the coupling could adversely effect the pumpset operation/3/.

3.1.3 Summary of Unit 8 Results

The vibration levels measured on the outlet piping were within the allowable range. The outlet piping data showed the flow to be much smoother in the outlet lines for flow in the same Reynolds number range as that of the inlet piping. The results suggest that there existed in the inlet flow a source of high turbulent flow excitation that was dissipated in the passage through the calandria. The results of the test of the clamp on the inlet pipe proved the clamp to be incapable of reducing the vibration to acceptable levels.

Following the completion of the Unit 8 work the decision was made to attempt to remove the source of excitation in the inlet line. From the Unit 6 and Unit 8 data the orifice plate in the inlet line was known to be a source of cavitation and broad band turbulence. The decision was made to replace the orifice plate with the energy dissipater which would yield the same pressure drop in the system but reduce the turbulence and cavitation produced by the single orifice plate. The performance of the dissipater was tested in Unit 5.

3.2 Unit 5 Measurements

The data from the vibration measurements in the inlet piping with the two stage energy dissipater in Unit 5 are documented in Table 6 for four pump operation and in Table 7 for three pump operation.

Vibration levels with four pumps in operation ranged from 18 to 52 mm/s peak. Levels with three pumps in operation ranged from 19 to 30 mm/s peak. As shown in the Table 8 comparison of Unit 6 (orifice) peak data with the Unit 5 (dissipater) peak data, the dissipater had the effect of reducing the

vibration levels in the critical locations 1 through 10 by at least 40%. The Table 9 comparison of overall RMS data for Unit 8 (orifice) and Unit 5 (dissipater) showed a similar reduction in vibration velocity. The reduction in flow noise was also significant and was immediately obvious in the vicinity of the piping.

The vibration levels in Unit 5 with four pumps in operation which were over 40 mm/s peak were fairly isolated occurrences. The acceptable levels at the other locations on the piping under the four-pump condition coupled with the low vibration levels at three pump operation led to the conclusion that the energy dissipater had adequately lowered the piping vibration to acceptable levels/7/. The dissipater reduced the scale of the turbulence generated in the flow restriction and produced earlier pressure recovery in the fluid downstream of the flow restrictor as compared to the performance of the orifice plate. The earlier pressure recovery significantly reduced the cavitation. The dissipater did not significantly effect the flow rates or pressure drop in the system.

4.0 CONCLUSIONS

The vibration monitoring program performed on the moderator piping in Units 8 and 5 yielded the following results.

4.1 Unit 8 Conclusions

4.1.1 Vibration levels on the outlet piping were well within the allowable range with four pump operation in the same flow range (Re ~10^6) as the inlet piping. The outlet piping results led to the conclusion that the cause of the high inlet piping vibration was due to a source of highly turbulent flow excitation unique to the inlet piping. The orifice plate in the inlet flow was identified as the largest source of the turbulence and cavitation.

4.1.2 The modal analysis performed on the outlet piping revealed a 30 Hz structural mode which, while not affecting the piping, could adversely affect pump performance. The close proximity of a piping structural vibration frequency to the pump operating frequency could cause excessive pump vibration. Detection of piping mode frequency in the pumpset operating response frequencies suggests that the coupling does exist.

4.1.3 The vibration levels on the inlet piping were not reduced by attempts to clamp the piping above the tee. This conclusion, coupled with 4.1.1 led to the decision to replace the orifice plate with a two-stage energy dissipater in Unit 5.

4.2 Unit 5 Conclusions

4.2.1 The two-stage energy dissipater successfully reduced vibration on the moderator inlet piping by a minimum of 40% to levels comparable with those measured on the outlet piping.

4.2.2 The dissipater did not significantly affect the flow rates or pressure drop in the system.

5.0 RECOMMENDATIONS

The following recommendations have been drawn from the conclusion of the vibration measurement program on Units 5 and 8 moderator piping:

5.1 The orifice plates in the moderator inlet piping should be replaced by the two-stage energy dissipaters in the remaining B-side units.

5.2 Further investigation of the moderator pump performance should be undertaken in light of the discovery of piping modes close to the pump operating frequency and the verification that low frequency modes at 6.5/7.5 Hz and 11.5/12.5 Hz observed on the pumps in commissioning work are piping natural frequencies/3/. These observations indicate some interaction between the pump and piping which would account for the high vibration levels observed on the pumps.

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TABLE 1: PNGS B U8 MODERATOR INLET PIPING RESPONSE FREQUENCIES

FREQUENCIES IN HZ

E-W		*N-S*	
FREE	CLAMPED	FREE	CLAMPED
9.5		10.5	
17.5	16.5	15.5	19.5
26.0	27.5		21.5
	30		34
			47
			74
98	98	98	98
		115	
		118	118

TABLE 2

PNGS B MODERATOR OUTLET PIPING
MODAL ANALYSIS: FREQUENCIES IN VICINITY OF PUMPS

LOCATION	FREQUENCIES In Hz		
	vertical	*N-S*	*E-W*
INLET OF PUMPS 1,2 3 (locations 7-12)	10,10.5,13,13.5, 14,16,16.5,23.5	7,7.5,10,10.5,13.5, 14,16,16.5,20,24, 26.5,27,29.5,37.5, 38.5,48,53	9.5,10,12,14.5,15, 20,21,21.5,24.5, 25,26,27.5,28.5, 29.5,31.5,32,37,48
INLET OF PUMPS 4&5 (locations 19-23)	9,9.5,10.5,11,11.5, 12,12.5,18,18.5,19, 19.5,23,25	9,9.5,11.5,12,18, 18.5,19.5,22,23.5, 29,32.5	6.5,7,11.5,12,18, 18.5,22.5,25,26.5, 28,29.5
OUTLET OF PUMPS (locations 29-40)	6.5,7.5,9,9.5,10.5, 11.5,12,13.5,14, 14.5,15.5,16.5,17, 19,19.5,21.5,24,25 26,28	7,7.5,9,9.5,10,10.5, 11.5,12,13.5,14, 14.5,16.5,17,18.5, 19,21,22,24,28,29, 30,32,33,35,38,50	6.5,7,9.5,10,10.5, 11.5,12,18.5,20, 25,26.5,27,28,29.5, 31,33,35,36

TABLE 3 : PNGS B U8 MODERATOR PIPING VIBRATION
INLET PIPING WITH FOUR PUMP OPERATION
PUMPS 1,2 3,4
(FILTER BANDWIDTH 4HZ-120HZ)

VELOCITY (mm/s peak)

INLET PIPE LOCATION	VERTICAL		EAST-WEST		NORTH-SOUTH	
	FREE	CLAMPED	FREE	CLAMPED	FREE	CLAMPED
1	76	60	60	86	17	15
2	69	63	56	74	15	15
3	86	100	62	112	38	54
4	80	74	58	92	42	39
5	94	60	47	32	60	42
6	82	70	50	38	75	44
7	-	52	42	-	70	72
8	62	78	54	104	96	106
9	56	60	40	62	72	112
10	88	120	48	42	22	26

TABLE 4: PNGS B U8 MODERATOR PIPING VIBRATION
INLET PIPING WITH FOUR PUMP OPERATION
PUMPS 1,2,3,4
(WIDE BAND)

VELOCITY (mm/s peak)

INLET PIPE LOCATION	VERTICAL		EAST-WEST		NORTH-SOUTH	
	FREE	CLAMPED	FREE	CLAMPED	FREE	CLAMPED
1	100	80	80	100	52	42
2	100	96	100	92	60	50
3	120	120	88	120	100	100
4	140	128	100	116	120	100
5	140	100	100	80	120	100
6	120	96	160	100	120	100
7	160	120	120	-	200	144
8	132	240	148	160	192	160
9	140	120	148	160	190	184
10	200	400	100	120	100	104

TABLE 5: PNGS B U8 MODERATOR PIPING VIBRATION
OUTLET PIPING WITH FOUR PUMP OPERATION
PUMPS 1,2 3,4
(WIDE BAND)

OUTLET PIPE LOCATION	VELOCITY (mm/s peak) VERTICAL	EAST-WEST	NORTH-SOUTH
1	30	30	14
2	35	20	40
4	20	20	22
6	25	25	20
11	30	22	22
12	18	30	20
13	22	30	10
14	25	-	28
16	20	20	30
18	35	18	37
20	18	19	24
22	20	12	30
30	36	28	20
32	14	40	20
33	16	20	18
34	18	20	20
39	32	30	20
40	20	32	14
41	22	24	13
44	28	22	28
45	14	16	18
48	20	32	22
49	14	24	12

TABLE 6: PICKERING UNIT 5 MODERATOR INLET PIPING* VIBRATION SURVEY

* orifice plate removed; energy dissipator installed

FOUR PUMP SURVEY

VELOCITY (mm/s peak)

LOCATION[1]	east		south		vertical	
	peak	rms o/a	peak	rms o/a	peak	rms o/a
1	33	-	24	-	40	10.3
2	37	7.6	20	2.6	44	-
3	-	6.3	52	11	26	4.6
4	27	7.8	50	4.7	43	9.4
5	38	6.6	36	8.4	48	7.6
6	41	7.7	38	8.5	44	9.2
7	-	-	36	7.2	33	5.5
8	40	6.9	35	6.4	40	7.6
9	39	6.4	38	6.8	36	6.3
10	-	-	33	6.2	18	3.5
17	23	4.4	28	5.6	36	7.0
18	29	6.1	38	6.8	31	7.2

[1] locations as shown in Figure 1.

TABLE 7: PICKERING 'B' UNIT 5 MODERATOR PIPING VIBRATION SURVEY

DISSIPATER INSTALLED

FOUR PUMP VS THREE PUMP OPERATION

VELOCITY IN mm/s peak

LOCATION *	*EAST*		*SOUTH*		*VERTICAL*	
	3-P	4-P	3-P	4-P	3-P	4-P
3	23	35	15	52	23	26
4	22	40	19	50	30	43
5	-	38	20	36	20	48
6	19	41	25	38	22	44

* locations as shown in Figure 1.

TABLE 8 : COMPARISON OF UNIT 6(orifice) and UNIT 5(dissipater) PIPING VIBRATION SURVEYS

FOUR PUMP SURVEY

	VELOCITY (mm/s peak)					
	east		south		vertical	
LOCATION [1]	*U 6*	*U 5*	*U 6*	*U 5*	*U 6*	*U 5*
1	60	33	3.2 *	24	70	40
2	64	37	1.6 *	20	70	44
3	95	35	88	52	76	26
4	90	30	66	50	60	43
5	88.5	38	90	36	44	48
6	85	41	95	38	51	44
7	95	-	70	36	25	33
8	107	40	70	35	38	40
9	100	39	90	38	40	36
10	60	-	9 *	33	158	18
17	50	23	50	28	40	36
18	80	29	70	38	40	31

[1] locations as shown in Figure 1

* -the data was heavily filtered to eliminate excessive flow noise overload and a mounted resonance problem in the accelerometer; it is likely that the filtering removed significant vibration data; the data for Unit 6 marked * is therefore assumed to be inaccurate .

TABLE 9: OVERALL RMS VIBRATION LEVEL COMPARISON BETWEEN UNIT 8 (free, orifice) and UNIT 5(free, dissipater)

FOUR PUMP SURVEY

	VELOCITY (mm/s rms)					
	east		south		vertical	
	U 8	*U 5*	*U 8*	*U 5*	*U 8*	*U 5*
LOCATION[1]						
1	12	-	3.4	-	15.1	10.3
2	11.2	7.6	3.5	5.4	15	8.8
3	12	6.3	7.4	3.8	17.3	4.6
4	14	4.9	7	10	15	7.3
5	11	6.6	12	7.3	16	8.1
6	11	7.7	13	8.5	17	6.5
7	10	-	15	7.2	-	5.5
8	11	6.9	21	6.4	12	7.6
9	10	6.4	18	6.8	12	6.3
10	4	-	4	6.2	16	3.5

1 - locations as shown in Figure 1

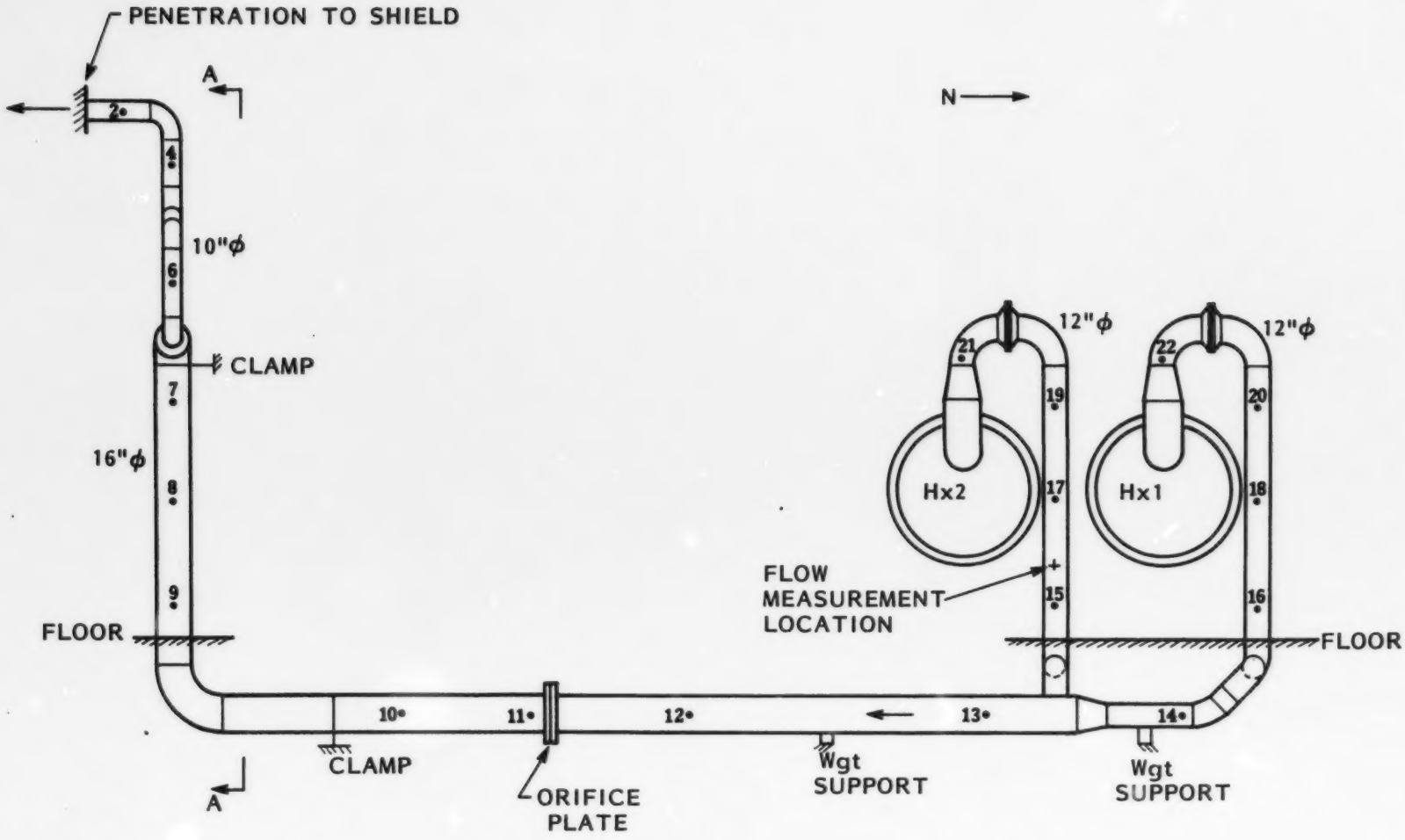
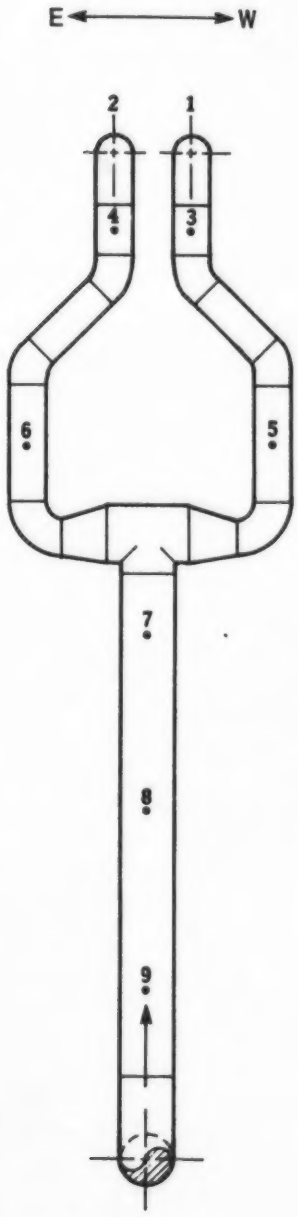


FIGURE 1

PICKERING NGS B MODERATOR INLET PIPING

88-180 176498-RD



VIEW A-A

FIGURE 2
MODERATOR INLET PIPING

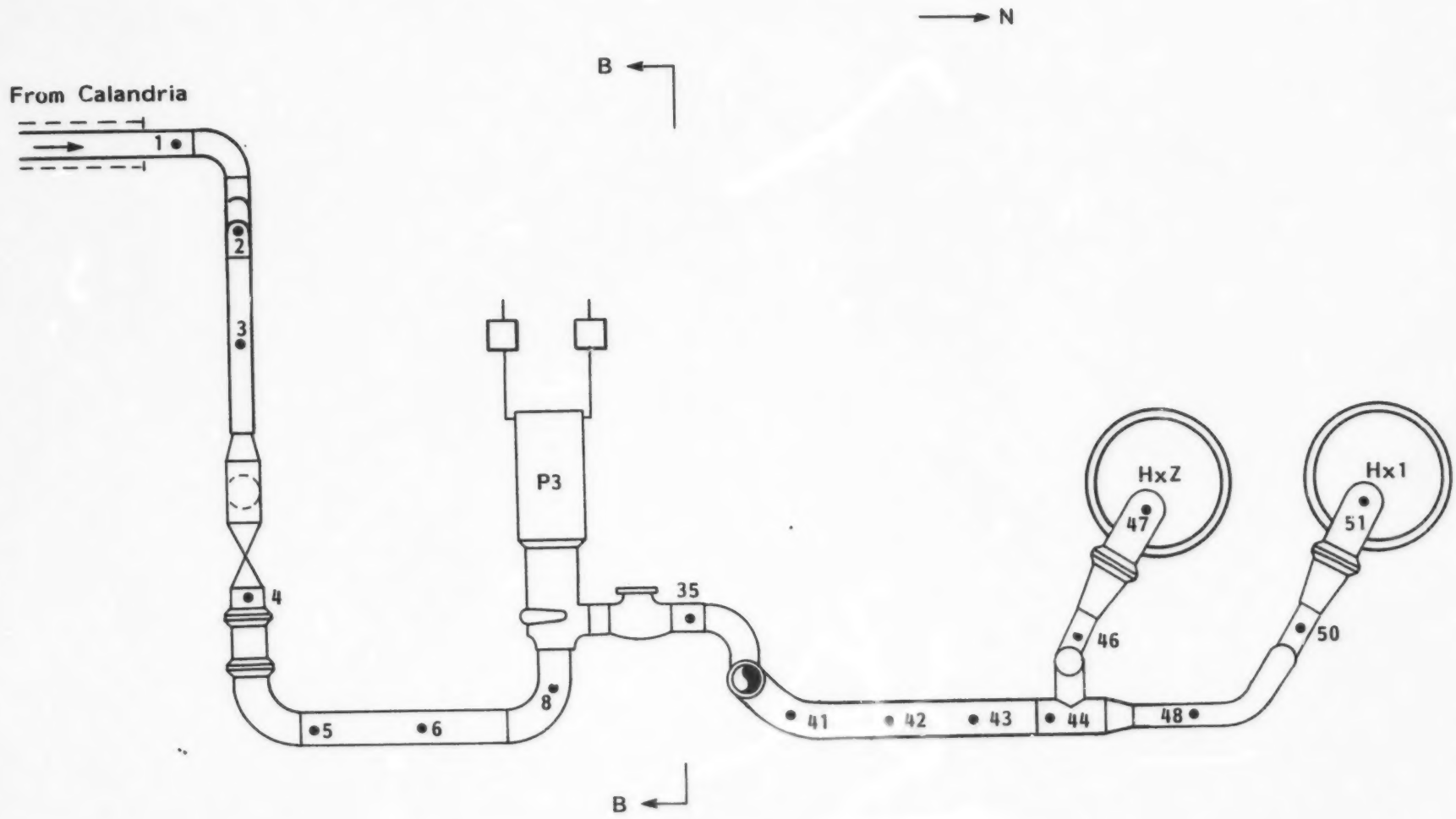


FIGURE 3

MODERATOR OUTLET PIPING & MEASUREMENT LOCATIONS

88-180

175555-RD

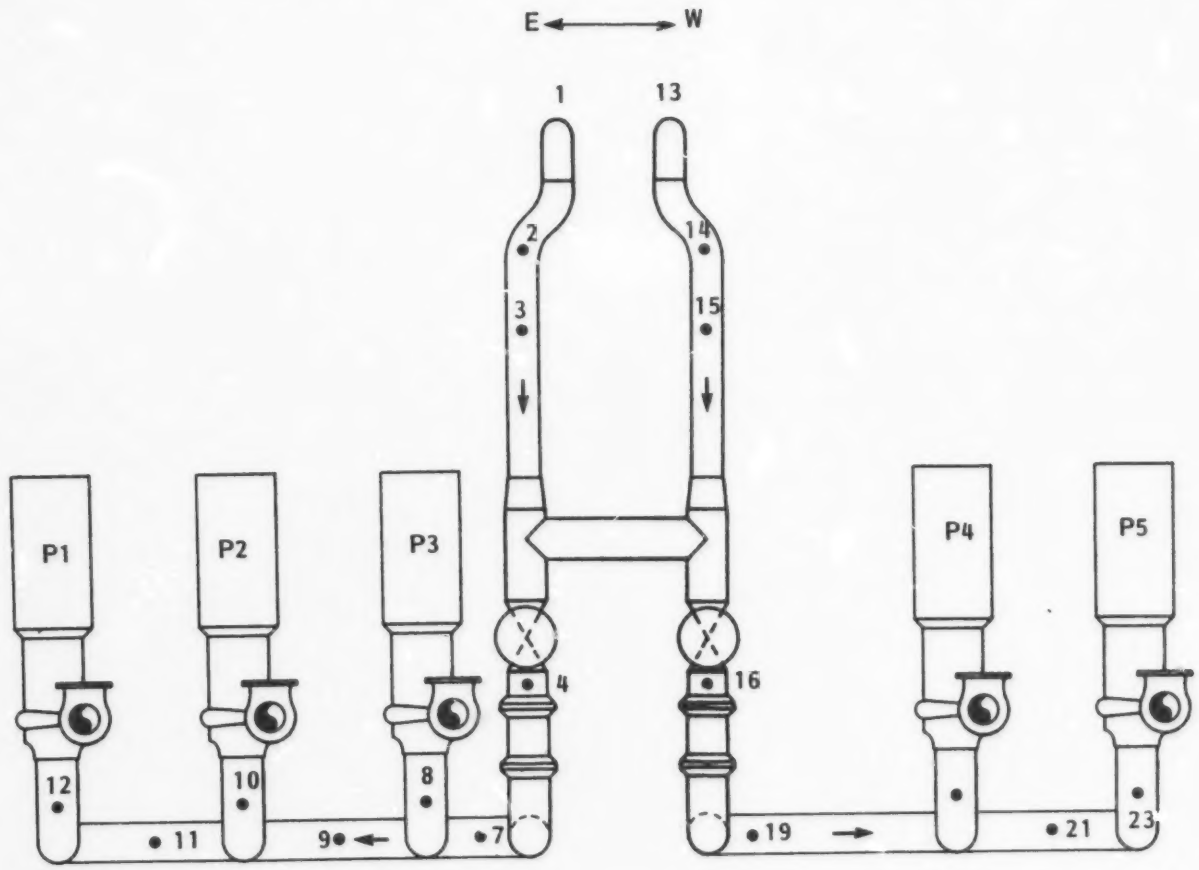


FIGURE 4
VIEW B-B: MODERATOR OUTLET PIPING

88-180
176556-RD

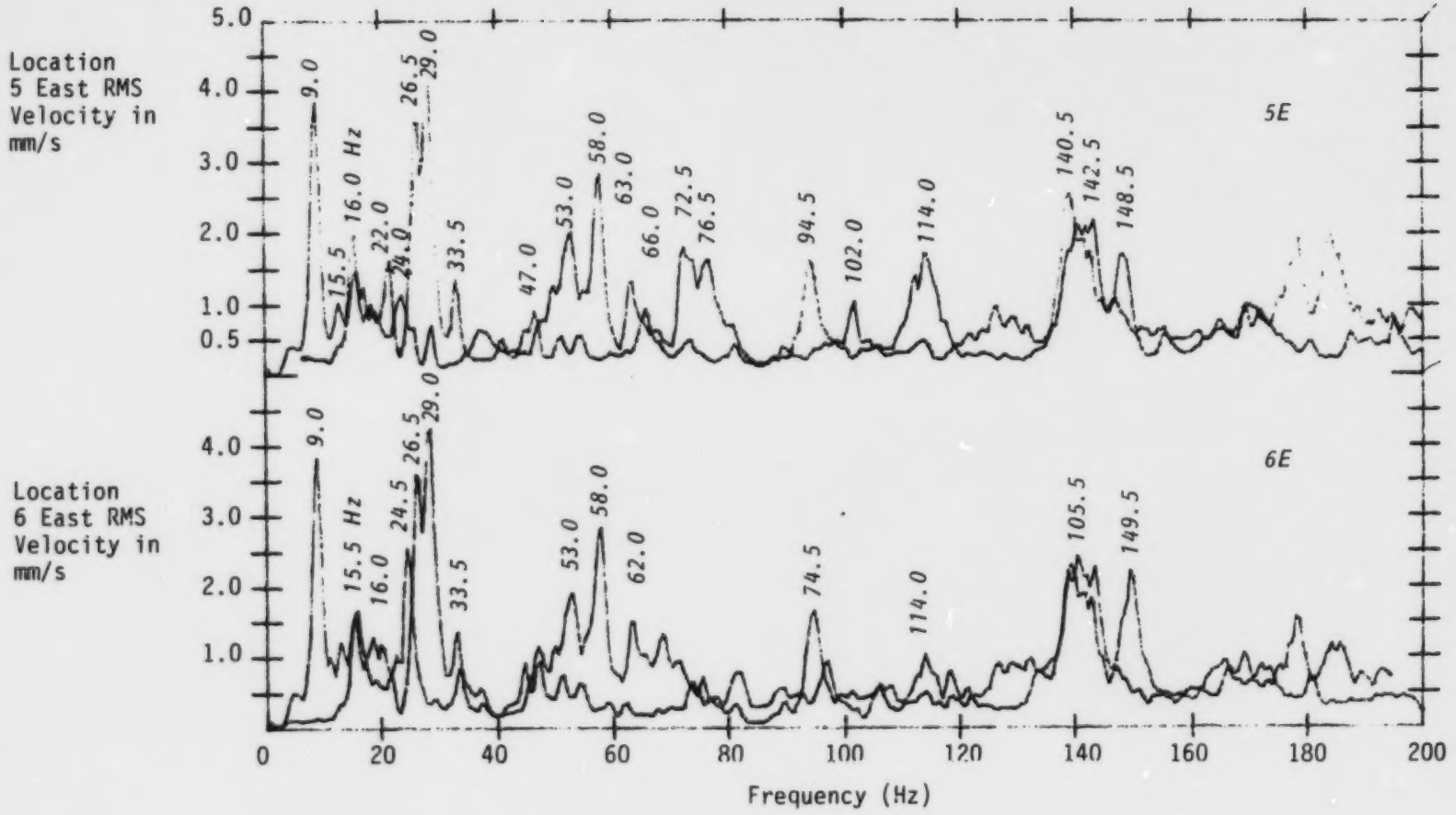


FIGURE 5

PICKERING NGS "B" UNIT 8 MODERATOR PIPING:
COMPARISON OF FREE AND CLAMPED VIBRATION SPECTRA AT
LOCATIONS 5 & 6 ON THE INLET PIPING WITH PUMPS 1, 2, 3 & 4 IN OPERATION

BLACK SPECTRA - FREE
RED SPECTRA - CLAMPED

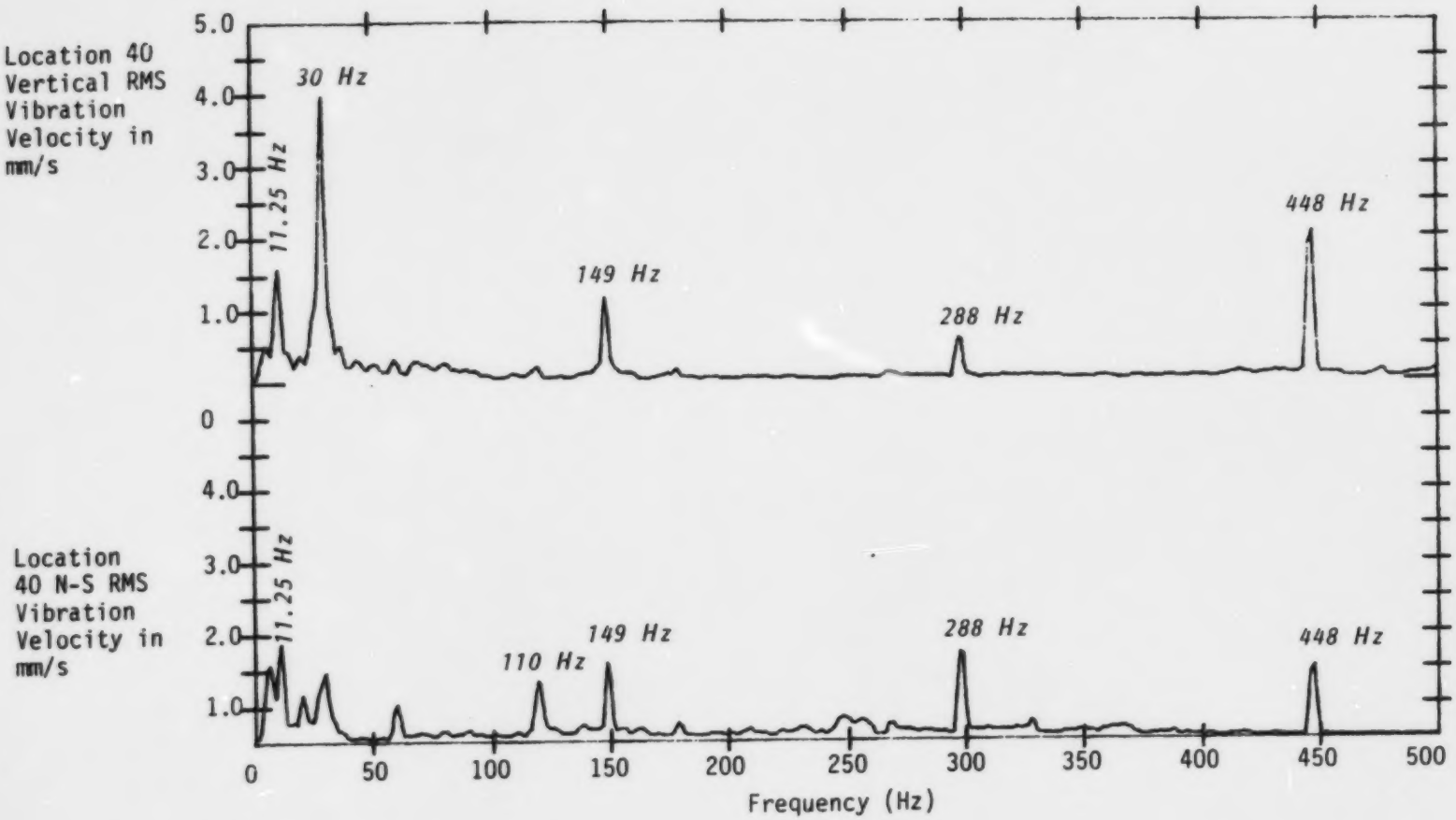


FIGURE 6

PICKERING NGS "B" UNIT 8 MODERATOR OUTLET PIPING:
VIBRATION VELOCITY SPECTRA FOR FOUR PUMP OPERATION
AT DISCHARGE OF PUMP 1, LOCATION 40 VERTICAL & N-S

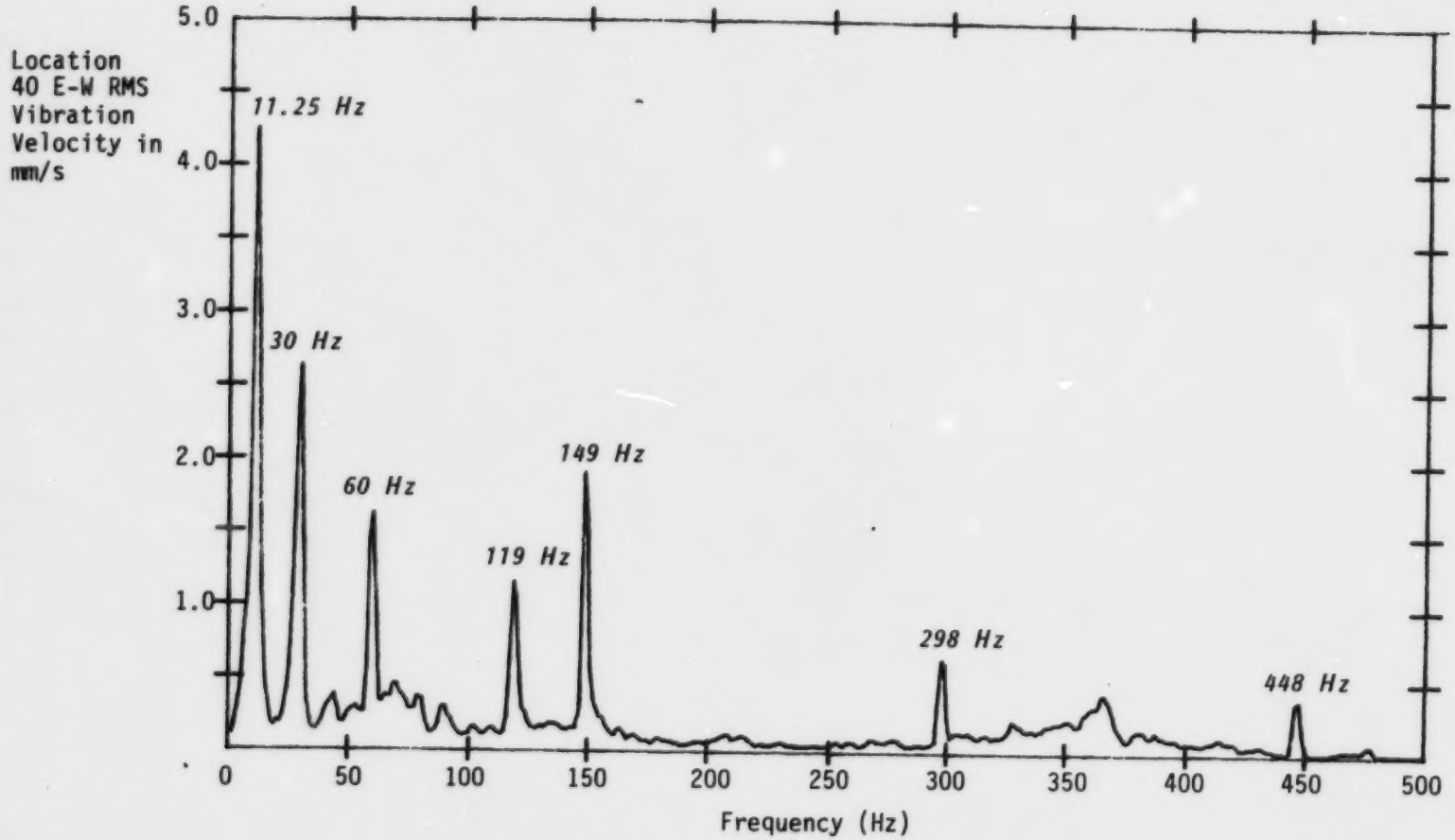


FIGURE 7

PICKERING NGS "B" UNIT 8 MODERATOR OUTLET PIPING:
VIBRATION VELOCITY SPECTRUM FOR FOUR PUMP OPERATION
AT DISCHARGE OF PUMP 1, LOCATION 40 E-W

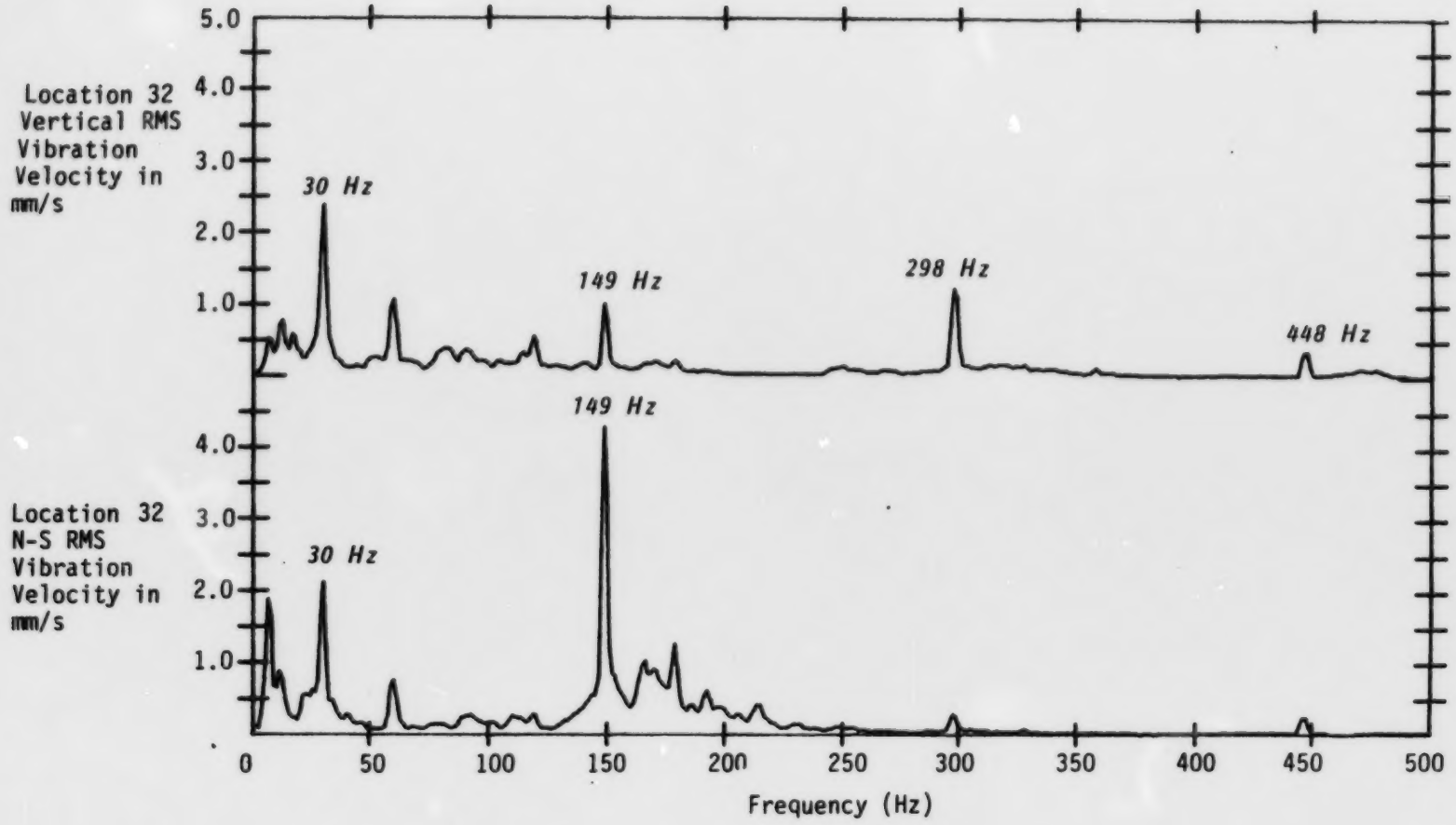


FIGURE 8

PICKERING NGS "B" UNIT 8 MODERATOR OUTLET PIPING:
VIBRATION VELOCITY SPECTRA FOR FOUR PUMP OPERATION
AT THE DISCHARGE OF PUMP 4, LOCATION 32, VERTICAL & N-S

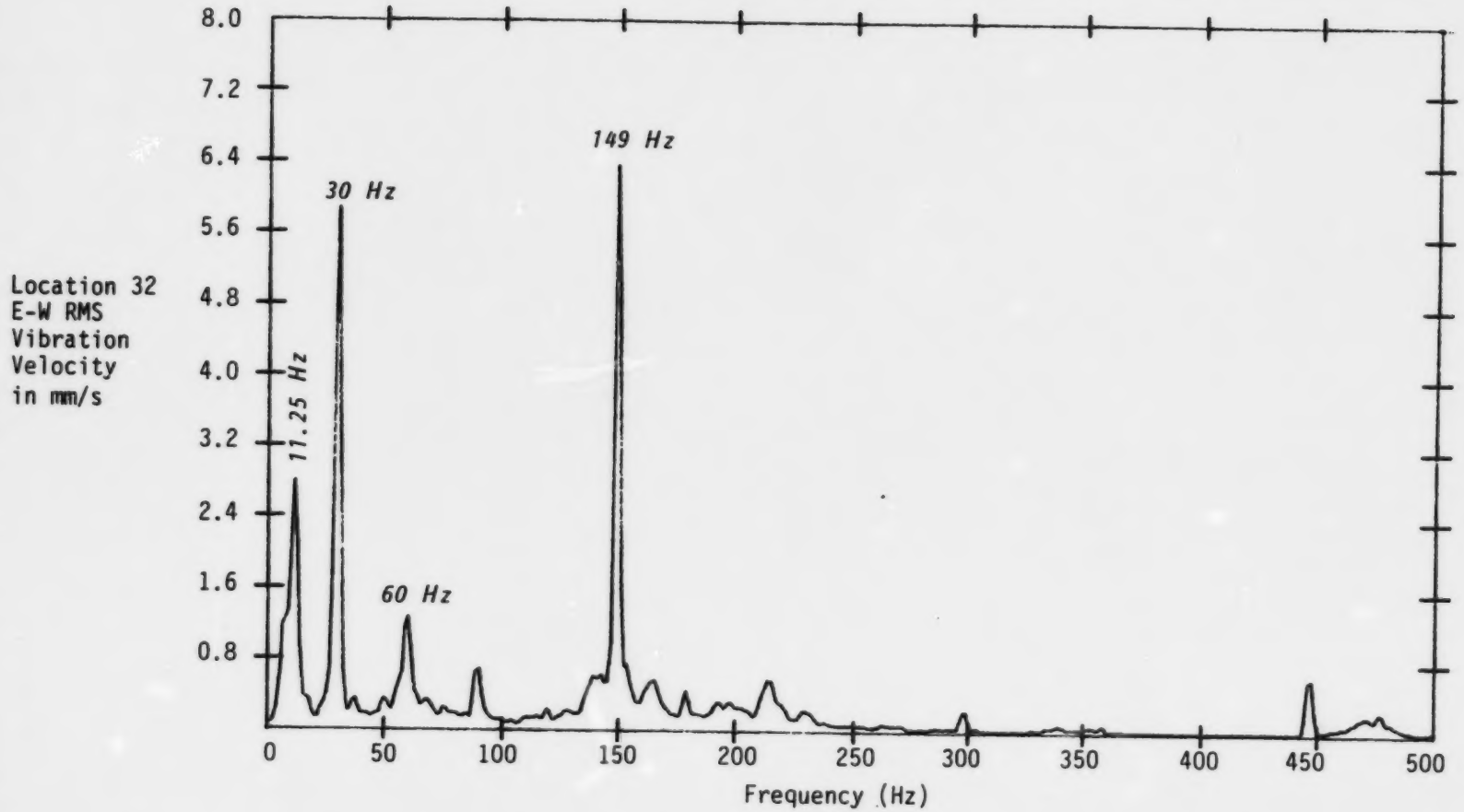


FIGURE 9

PICKERING NGS "B" UNIT 8 MODERATOR OUTLET PIPING:
VIBRATION VELOCITY SPECTRUM FOR FOUR PUMP OPERATION
AT THE DISCHARGE OF PUMP 4, LOCATION 32 EAST-WEST

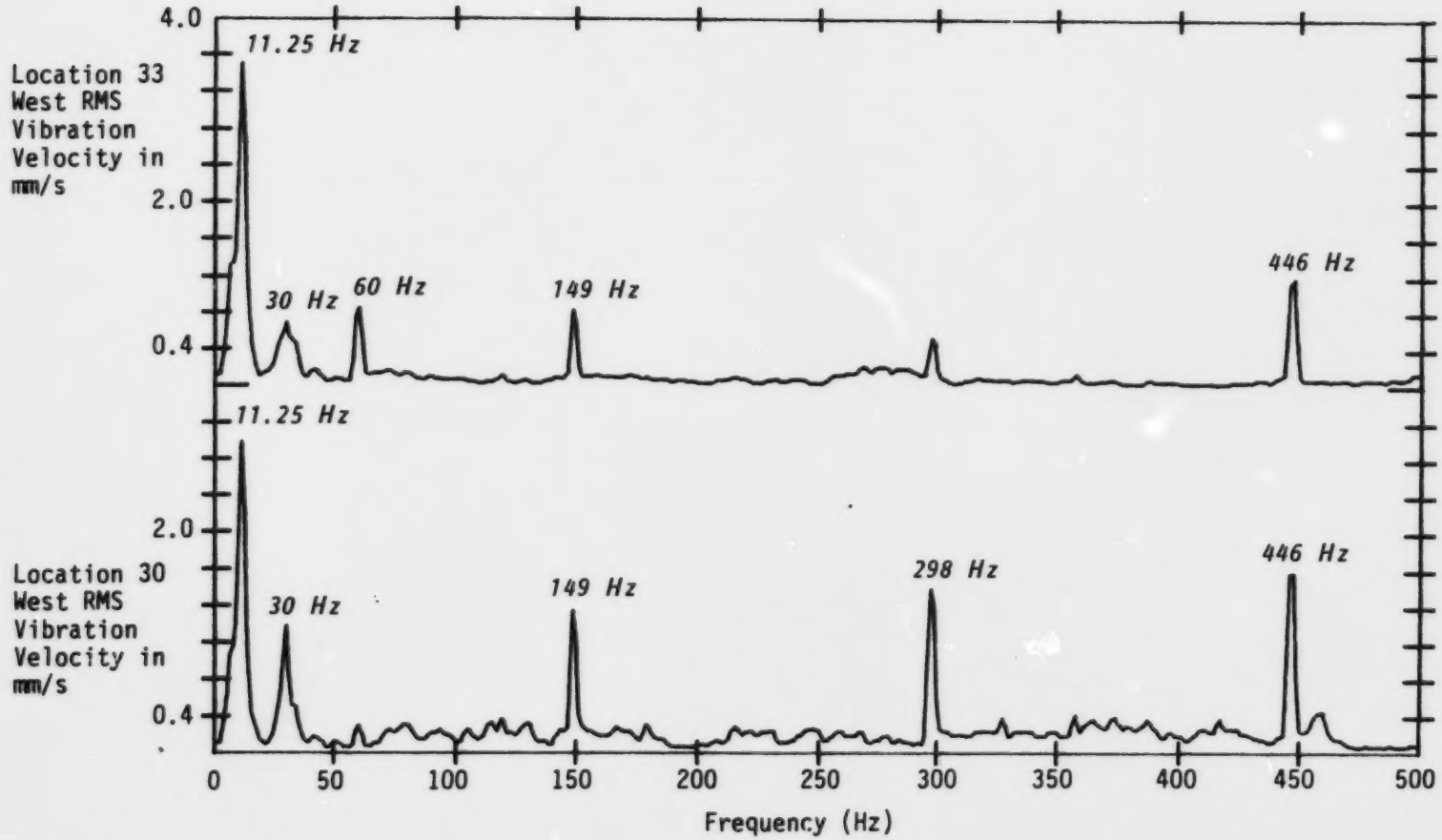


FIGURE 10

PICKERING NGS "B" UNIT 8 MODERATOR OUTLET PIPING:
VIBRATION VELOCITY SPECTRA FOR FOUR PUMP OPERATION
AT LOCATION 33 WEST AND THE DISCHARGE OF PUMP 5, LOCATION 30 WEST

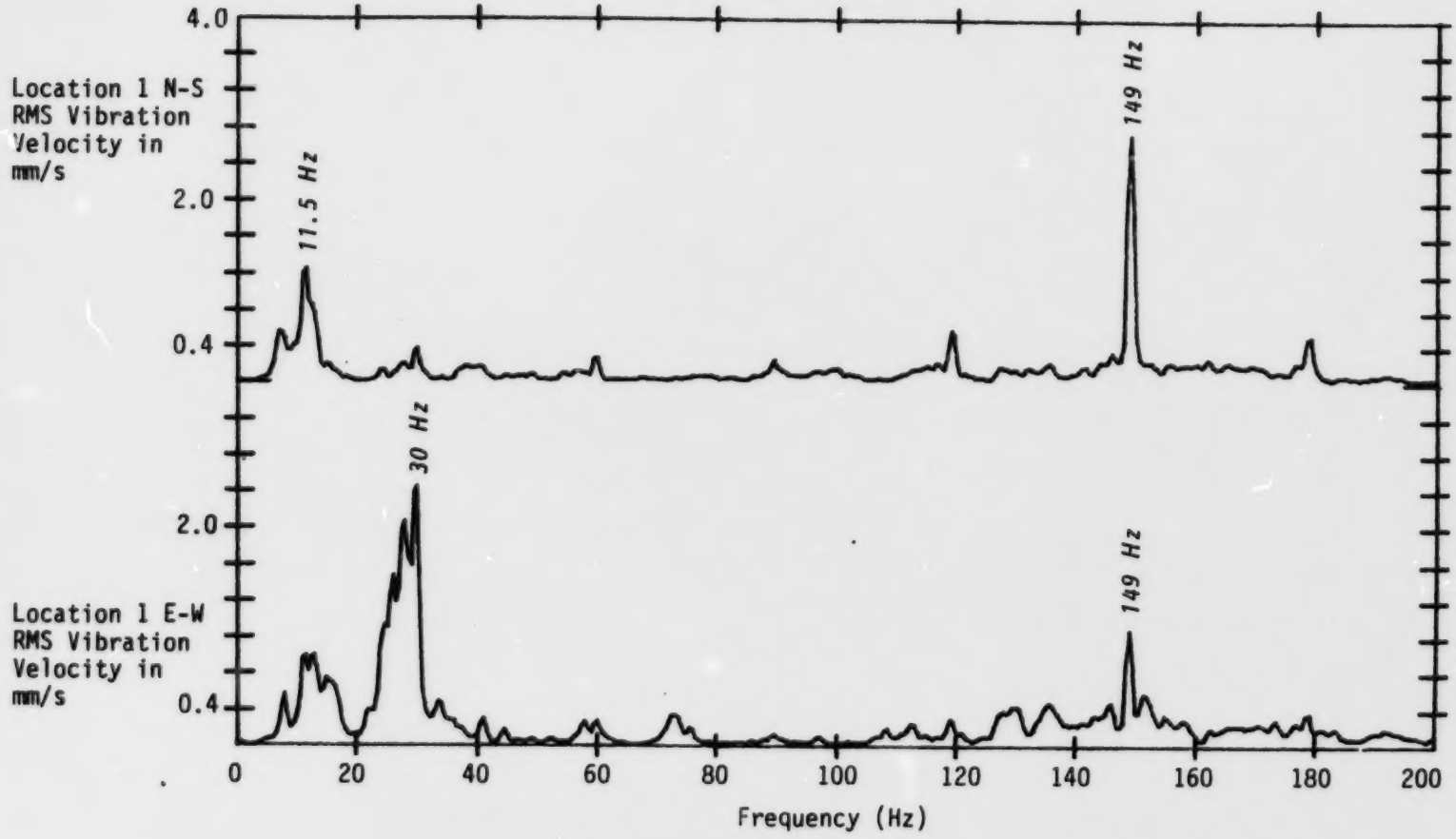


FIGURE 11

PICKERING NGS "B" UNIT 8 MODERATOR OUTLET PIPING:
VIBRATION VELOCITY SPECTRA FOR FOUR PUMP OPERATION
AT LOCATION 1 NEAR THE SHIELD PENETRATION

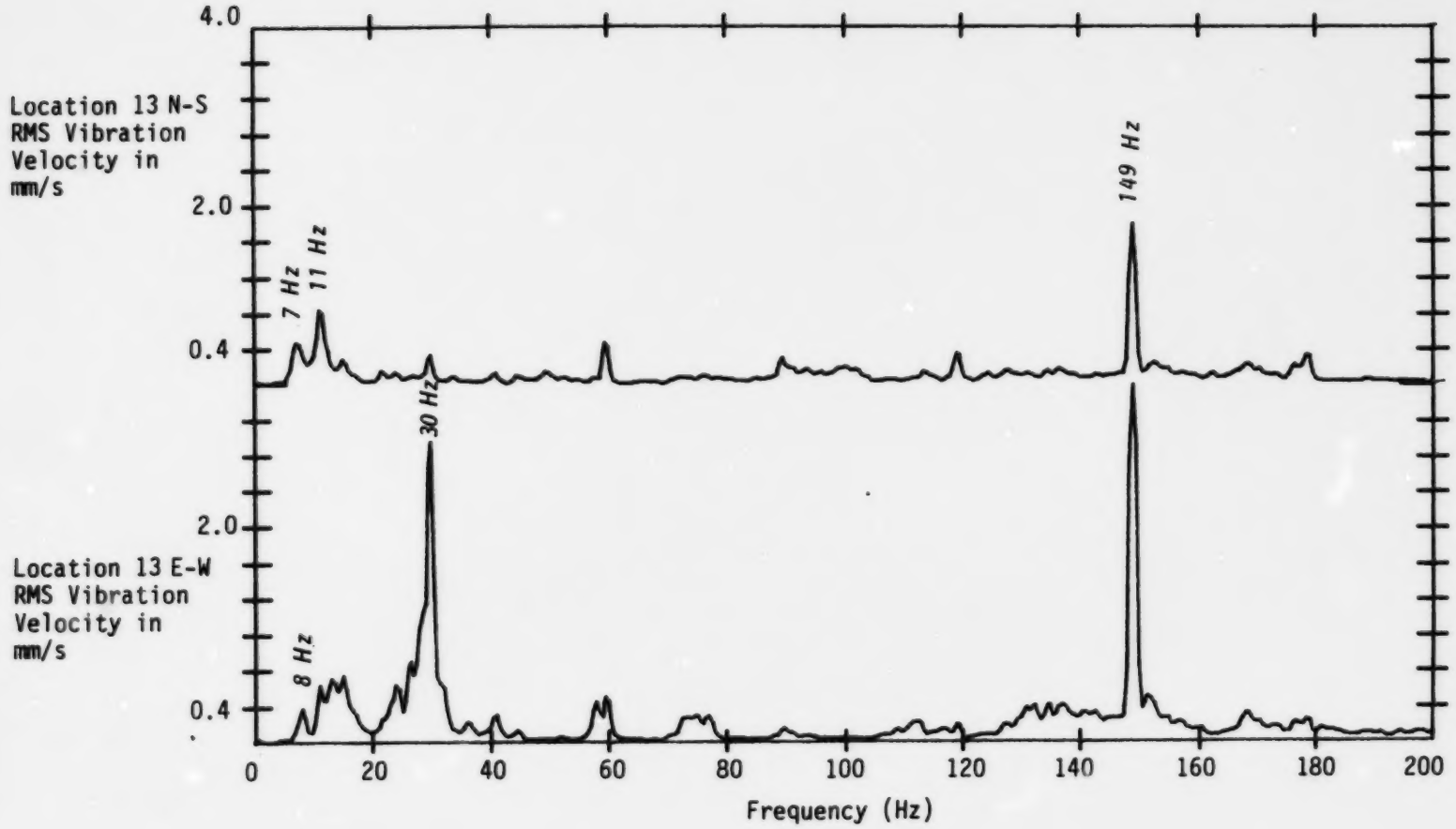


FIGURE 12

PICKERING NGS "B" UNIT 8 MODERATOR OUTLET PIPING:
VIBRATION VELOCITY SPECTRA FOR FOUR PUMP OPERATION
AT LOCATION 13 NEAR THE SHIELD PENETRATION